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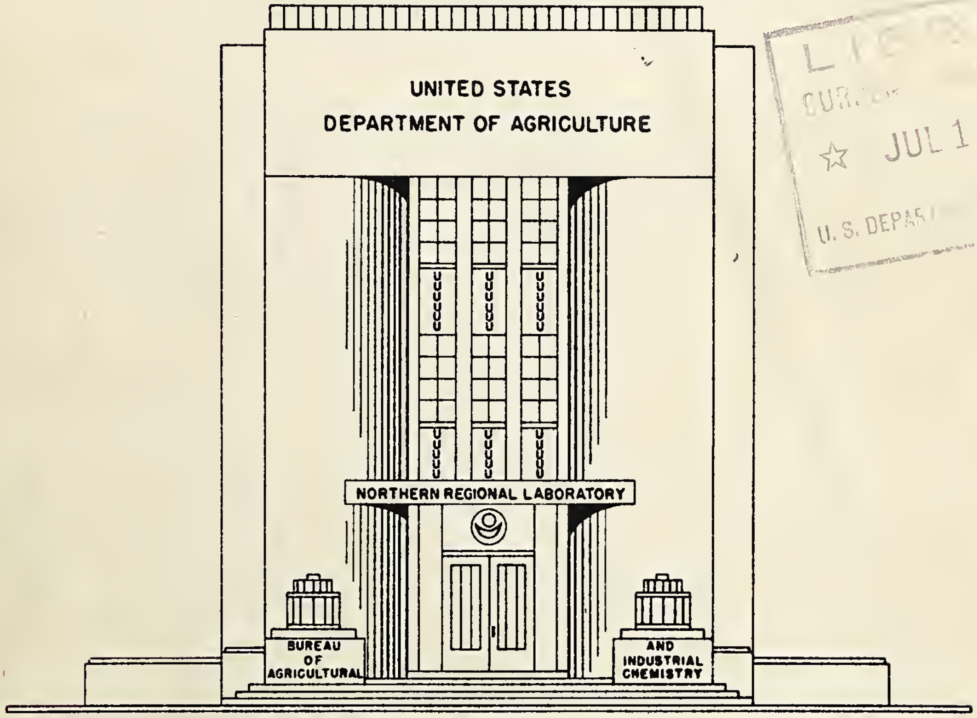
UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Research Adminstration
Bureau of Agricultural and Industrial Chemistry

NUT SHELLS AND FRUIT PITS THEIR COMPOSITION, AVAILABILITY, AGRICULTURAL AND INDUSTRIAL USES



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By T. F. Clark and E. C. Lathrop

NORTHERN REGIONAL RESEARCH LABORATORY
PEORIA, ILLINOIS

FEBRUARY 1953

NUTSHELLS AND FRUIT PITS--THEIR COMPOSITION, AVAILABILITY, AGRICULTURAL AND INDUSTRIAL USES

By

T. F. Clark[1] and E. C. Lathrop[2]

The Northern Regional Research Laboratory, Peoria, Illinois, is one of four large research laboratories established, under authority of the Agricultural Adjustment Act of 1938, by the U. S. Department of Agriculture and placed under the administration of the Bureau of Agricultural and Industrial Chemistry of the Agricultural Research Administration.

The functions of these laboratories are to conduct researches into and to develop new scientific, chemical, and technical uses of, and new and extended markets and outlets for, farm commodities and the products and byproducts thereof. The commodities being worked on in the Northern Regional Research Laboratory are wheat, corn and other cereal crops; soybeans and other oilseed crops, excepting cottonseed and peanuts; and agricultural residues.

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NUT SHELLS AND FRUIT PITS--THEIR COMPOSITION, AVAILABILITY, AGRICULTURAL AND INDUSTRIAL USES

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INTRODUCTION

Nut shells and fruit pits accumulate in quantity about cracking plants, canneries, and similar food-processing plants. Their presence about these plants presents not only a nuisance but a hazard and an expense. Under favorable conditions and with proper handling, these residues can be converted into profit to the processors. Efforts to maintain and improve the national economy require that industry eliminate its wastes and make more effective use of byproducts. These requirements are being increasingly recognized, and many branches of industry are now converting what has heretofore been considered "waste" into salable products. An outstanding example of "waste" utilization is the practice of the pulping and wood-processing industries in converting their wastes into useful chemicals and structural materials, such as resin-bonded panel boards. Practical use of shells and pits accumulating in the nut-cracking and fruit-processing industries can likewise be promoted.

For the purpose of this discussion, the agricultural residues include only those materials that accumulate in quantities large enough to make their processing and use worth while. They comprise the pits of apricots, cherries, peaches, and dates, and the shells of almonds, coconuts, filberts, peanuts, pecans, and of both English (or Persian) and black walnuts. Pits of certain fruits, such as prunes, have not been considered and certain of the nut shells have been omitted from this discussion because the quantities available from commercial processing are insufficient for industrial use. Of the materials considered here, it is estimated that more than 1 billion pounds are available annually within the United States.

Attempts to use agricultural residues in commercial operations are not new. Many scientific paper, patents, and proposed methods for utilization of agricultural residues are found in the literature. Only in very recent years, however, have practical uses for these residues been developed and exploited. Failure of many of the past developments and proposed methods has resulted too frequently from the false assumption that these agricultural materials were available at little or no cost and that low cost substitute products might be made from them. Also, too little consideration has been given to merchandising the processed residues and to sound business management in their industrial utilization.

As a result of a study of the successes and failures in the field of waste utilization, Lathrop and Shollenberger *(35)*[3] proposed several simple guiding principles for the development of residue utilization. These principles are:

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[3] Numbers in parenthesis refer to Literature Cited, page 20

1. Establishing sound economical methods for the collection or purchase and the preservation of the nut shells and fruit pits.

2. Establishing uses based on superior or unusual chemical and physical characteristics of the nut shells and fruit pits.

3. Avoiding the production of materials having little value.

4. Maintaining a policy of sound merchandising and business management.

In the early 1930's a plant for grinding walnut shells was established on the Pacific Coast *(37)*. Although many difficulties and hazards were encountered during early operation of the plant, this business is now firmly established largely because of constant vigilance and sound development by the management. This organization makes a complete line of ground products from nut shells and fruit pits. The products include flours for use in plastics, adhesives, and insecticides, and grits for use in blast-cleaning, burnishing and polishing, in nonskid paints, and in dynamite manufacture.

Use of processed nut shells and fruit pits was stimulated by military requirements during World War II. The Army Air Force used soft grits from walnut shells and apricot pits in routine cleaning of aircraft engine parts. The supplies of phenolic resins were extended through use of flour from English walnut shells. Molded phenolic plastics with superior surface characteristics were claimed for compounds containing very fine flours from walnut shells.[4]

With the entry of more grinders into the business during the late 1940's and early 1950's the use of processed materials from nut shells and fruit pits for civilian purposes has expanded. At the Northern Regional Research Laboratory, it has been recognized that full-scale commercial utilization of ground shell products can be expected only after practical methods for their processing and use are developed. For that reason, considerable research has been directed to commercial utilization of these residues. This work is continuing.

COMPOSITION

Structural and Physical Characteristics

Structurally and physically the shells (endocarp) of nuts and fruit pits have many characteristics in common. During growth of nuts and fruits, the pits or shells have an outer covering or husk (mesocarp) which often cover the entire shell. In fruits this husk is actually the fleshy portion for which the plant is cultivated. Although this fleshy material is removed at canneries or prior to delivery to shell-processing plants, some of this material, generally fibrous, may still be attached to the shell's outer surfaces.

One striking difference between nut shells (or outer covering) and fruit pits (from inside the fruit's flesh) is the kernel inside the fruit pit. Nuts are cracked for removal of the meats or kernels only; broken fragments of the meats are not purposely left in the shells. With fruit pits, however, the kernel ~~generally remains~~ within the shell unless, in the particular method of processing at a cannery, the shell is split and the kernel released. For example, apricot pits in California are cracked to recover the whole kernels, which are marketable.

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[4] Private communication from J. W. Ayers, Agrashell, Inc., Los Angeles, California, December 15, 1949.

The outer surfaces of shells vary from very rough to smooth, soft to hard, and fibrous to essentially nonfibrous. The physical structure of the shells varies considerably from their outer to inner surfaces. Dahl *(23)* states that the shell of the English walnut is composed of three distinct layers. The outer or hardest layer is composed of densely packed cells, essentially isodiametric and colorless. The cell walls are highly lignified. The middle layer is composed of irregular-shaped cells, larger, more spongy, and with thinner walls. Cells of the inner layer are thin-walled, loosely packed, and serve as a lining. Shells of pecans and filberts also contain an appreciable quantity of spongy lining material.

In addition to the spongy lining materials many nuts also contain parchment-like or woody tissues which act as partitions or septa between the cotyledons or segments of the kernels. These materials generally remain with the shells after the cracking and shelling operations.

Because shells of nuts become available for industrial processing after cracking operations, the shape of the original nut shell is not significant. However, fruit pits very frequently accumulate without rupture of their shells and thus still contain kernels. Shape and size of the pits influence the manner in which pit shells may be cracked and the kernels removed. Peach pits, of a flattened ovoid shape, may be as large as 1-1/2 inches in length, 1 inch wide along the suture, and 3/4 inches high across the suture. Cherry pits approximate 3/8 inch long, 5/16 inch wide, and 1/4 inch across the suture. Broken sections of coconut shells may be as large as 3 or 4 inches in one dimension.

Chemical Composition

A high degree of similarity in composition exists between the shells of nuts and fruit pits. Proximate analyses made by Nelson and others *(41)* at the Northern Regional Laboratory are presented in table 1. The most striking differences are shown by the results obtained for date pits. Solubilities of these in organic solvents and in 1 percent sodium hydroxide are relatively high; lignin and pentosan values low, and alpha-cellulose content high.

Analyses reported above do not include tannins which are present in significant quantity in some nut shells. Pecan shells and shell liners, for example, have been studied closely by the Eastern Regional Research Laboratory. The tannin content of the outer shells ranged from 0.4 to 1.1 percent, while that of the lining material ranged from 25.6 to 47.9 percent depending upon variety and the locality in which the nuts were grown.[5]

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[5] Private communication of J. S. Rogers to P. A. Wells, Director, Eastern Regional Research Laboratory, U. S. Department of Agriculture, Philadelphia, Pennsylvania, March 29, 1949.

Table 1. *Proximate analyses of shells of nuts and fruit pits, dry basis (41)*

Type of Shell	Crop Year	Solubility in				pH of Hot Water Extract	Constituents							
		One Percent Sodium Hydroxide	Alcohol-Benzene	Acetone	Hot Water		Ash	Silica in Ash	Nitrogen	Pentosans	Cutin	Lignin	Lignin, Corrected for Cutin	Alpha-Cellulose[1]
		Percent	*Percent*	*Percent*	*Percent*		*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Almond, hard	1946	17.8	4.2	2.4	4.4	5.2	1.0	5.8	0.19	34.2	0.4	27.5	27.1	23.6
Almond, soft	1946	27.9	2.6	3.9	11.9	5.0	3.1	3.2	.32	31.0	0.0	24.9	24.9	22.9
Apricot pit	1946	14.1	1.1	1.3	2.1	5.0	0.7	14.9	.12	32.8	0.9	31.0	30.1	27.2
Black walnut	1945	13.7	1.9	1.5	2.5	5.0	0.3	51.7	.20	28.3	12.7	43.5	30.8	28.1
Cherry pit	1948	19.9	4.4	3.2	6.5	4.5	0.8	-	-	27.9	-	34.8	-	22.8
Coconut	1946	22.0	3.0	3.7	3.3	5.4	0.7	2.9	.12	31.6	0.3	34.2	33.9	24.3
Date pit	1946	37.4	11.1	11.3	12.0	5.8	1.1	6.5	.96	2.9	1.5	10.6	9.1	39.6
English (Persian) walnut	1946	18.5	1.1	3.2	3.5	4.1	0.8	12.0	.17	29.5	0.7	38.7	38.0	25.2
Filbert	1944	13.3	1.8	1.8	2.2	4.8	0.7	31.7	.16	29.4	10.0	44.5	34.5	25.8
Peach pit[2]	1946	14.8	1.5	1.7	2.3	4.6	0.4	21.9	.15	31.1	1.7	38.9	37.2	22.6
Peanut	1943	44.0	6.4	6.4	11.2	6.6	8.8	59.8	1.49	16.8	3.7	28.7	25.0	25.1
Pecan	1946	25.5	1.1	1.9	7.8	5.0	1.8	27.1	0.24	26.0	0.5	46.2	45.7	19.7
Pecan, tannin-extracted	1946	24.0	2.9	2.6	1.4	4.9	1.5	2.3	.26	25.2	0.3	43.6	43.3	22.7

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[1] Monoethanolamine method, ash-free and corrected for pentosans.

[2] Averages for pits obtained from California and Washington.

Table 2.-*Proximate analyses of several nut shells as reported by Phillips and Goss (46)*

Shells	Solubility in			Constituents					
	One-percent Hydrochloric Acid	Alcohol-Benzene	Hot Water	Ash	Nitrogen	Pentosans	Methoxyl	Lignin	Cellulose
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Almond	33.1	6.4	12.7	1.9	0.4	26.6	5.3	17.1	26.1
Coconut	29.7	4.6	2.8	0.6	0.1	30.1	5.8	27.3	28.3
English walnut	33.1	4.4	8.1	1.6	0.3	26.3	7.1	21.0	28.2
Filbert	29.1	1.6	4.9	0.8	0.2	28.4	5.6	30.5	26.3
Pecan	26.2	3.1	7.8	1.6	0.3	19.7	5.5	35.5	21.8

The investigations at the Northern Laboratory did not include studies on the pit kernels. The results of numerous investigations made on kernels have appeared in the literature.

Other data on the proximate composition of nut shells have been reported by Phillips and Goss *(46)*, table 2, and by Child and Ramanathan *(16)*. Differences in data reported show differences that can be anticipated because of differences in varieties, growing seasons and conditions, and in the analytical methods employed by the various investigators. In a study of the composition of shells, oil, and meats of pecans by Whitehead and Warshaw *(59)*, analyses of the shell were limited to a qualitative analysis of the shell ash.

AVAILABILITY AND INDUSTRIAL PROCUREMENT

Proportionate Weight of Shells in Nuts and Fruit Pits

Fruits and nuts are cultivated and harvested for their value as food. Consequently, production data for shells and pits must be calculated from statistics reported for fruit or nuts, shelled or in-shell. Fruit processors report that dry pits of peaches and cherries represent about 4 percent of the weight of the fresh fruit, although some have indicated values as high as 7 percent. The values are variable, of course, depending upon specific varieties and growing conditions. Representative values for the relative proportions of pits and shells in fruits and nuts, respectively, are shown in table 3.

Commercially available dried peach pits obtained from California and Washington contained approximately 6 and 2 percent by weight of kernels, respectively. Because many pits had been sawed during fruit packing, loss of kernels could be anticipated, so that the difference in these observations is not surprising. In the pits from Washington, approximately 5 percent of foreign material, including dirt, fine shell and kernel fragments, was present; only 1 percent of such materials was present in the California pits.

Cherry pits obtained from a packer processing brined cherries were dried at 175° F. and analyzed 3 weeks later for residual pulp, kernels, and shells. Results are shown below:

	Percent
Residual pulp	0.1
Kernels	18.2
Shells	81.7

Supply

The potential annual supply of shells from nuts and fruit pits can be estimated from the production and commercial utilization of the crops. Annual production and disposition of almonds, apricots, cherries, dates, English walnuts, filberts, peaches, peanuts, and pecans are shown in tables 4 to 12. These tables present data for several

Table 3.- *Approximate relationship of nuts in-shell or fresh fruits to shells or pits, respectively*[1]

Nut or fruit	Weight of nuts in-shell equal to 1 pound of meats	Portion of nut in-shell or fresh fruit available as shell or pit (including kernel)
	Pounds	*Percent*
Almonds:		
California	2	50
Imported	3 1/3	70
Black walnuts	8 1/3	88
Coconuts		10-15
English (Persian) walnuts	2 3/8	58
Filberts	2 1/2	60
Peanuts	1 1/2	33 1/3
Pecans:		
Seedling	2 5/8	62
Improved varieties	2 3/8	58
Apricots		4
Cherries		4
Peaches:		
Freestone		4-7
Clingstone		4

---

[1] These relationships have been compiled from information published annually in "Agricultural Statistics," U. S. Dept. Agriculture, Washington, D. C., and private communications from various nut crackers and fruit processors.

Table 4.-*Production and imports of several fruits and nuts for the period 1946 - 1951*[1]

Fruit or nuts	Year					
	1946	1947	1948	1949	1950	1951
	Tons	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
Almonds (California)						
Production	37,800	29,200	34,000	43,300	37,700	42,700
Imports	15,082	19,742	17,176	2,431	-	-
Dates (California)						
Production	16,720	10,180	16,240	14,100	15,060	-
Imports	22,592	9,850	17,333	15,006	-	-
English (Persian) walnuts						
Production: California	63,000	59,000	62,000	80,200	58,000	68,300
Oregon	8,900	5,600	9,100	7,900	6,300	9,100
Imports	-1,829	-1,992	1,710	5,450	-	-
Filberts						
Production: Oregon	7,300	7,700	5,300	9,700	6,000	6,100
Washington	1,150	1,100	1,140	1,440	680	820
Imports	13,451	4,672	8,641	7,236	-	-
Olives (California)						
Production	48,000	40,000	58,000	35,000	43,000	67,000
Crushed for oil	14,300	19,400	33,600	7,900	9,900	-
Other processing	5,900	6,100	10,000	5,900	7,600	-

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[1] Compiled from data published by the U. S. Dept. Agriculture:
Reference 53. - 1948, p. 187; 1951, pp. 187, 193, 278, 279, 281.
Reference 54
Reference 55. - November 9, 1951, p. 16; August 1, 1952, p. 51.

Table 5. *Production and utilization by States of apricots for the period 1946 - 1951*[1]
[*Apricot pits, wet basis, represent 8 percent of the fresh fruit; dry basis, 4 percent*]

Year	Production				Farm household use and fresh	Commercial Utilization				
	Calif.	Wash.	Utah	U.S. Total		Canned	Dried	Frozen	Other	Total
	Tons	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
1946	306,000	27,300	5,400	338,700	49,610	167,990	98,750	21,950	400	289,090
1947	169,000	28,000	4,500	201,500	44,910	66,480	84,200	3,830	120	154,630
1948	219,000	20,300	7,300	246,600	44,370	104,210	68,200	1,290	90	173,790
1949	165,000	26,400	6,200	197,600	43,560	61,990	78,400	490	310	141,190
1950	213,000	1,600	400	215,000	29,450	103,750	77,800	4,100	0	185,650
1951	172,000	4,800	6,400	183,200	-	-	-	-	-	-

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[1] Compiled from data published by the U. S. Dept. Agriculture:
Reference 53 - 1946, p. 182, 1947, p. 181, 1950, p. 183; 1951, pp. 165, 167.
Reference 55 - October 1, 1951, p. 51; June 10, 1952, p. 20; August 1, 1952, p. 51.

Table 6.-*Production of cherries for the period 1946 - 1951, and average production and utilization by areas for 10 years 1941 - 1950*[1]

[*Cherry pits, wet basis, represent 8 percent of the fresh fruit; dry basis, 4 percent*]

Kind and Location	Production						Averages for 1941 - 1950				
	1946	1947	1948	1949	1950	1951	Production U. S.	Farm household use and fresh	Canned	Frozen	Brined
	Tons	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
Sweet											
Great Lakes States	6,800	7,380	7,960	11,370	14,910	14,920	8,410	4,030	870	180	2,980
Washington-Oregon	63,200	36,400	39,800	73,200	33,900	29,400	47,870	21,440	10,910	930	11,720
California	34,000	28,000	23,500	44,000	31,000	19,800	29,650	14,250	5,690	870	8,500
Western States[2]	8,370	7,490	8,360	9,130	2,240	7,670	6,550	4,690	740	275	810
Total	112,370	79,270	79,620	137,700	82,050	71,790	92,480	44,410	18,210	2,255	24,010
Sour											
Great Lakes States	102,700	80,020	122,760	100,510	148,360	144,000	89,180	12,300	48,970	29,900	1,220
Western States, all	14,550	12,850	12,000	12,020	8,280	14,240	12,710	4,760	4,120	3,920	-
Total	117,250	92,870	134,760	112,530	156,640	158,240	101,890	17,060	53,090	33,820	1,220
TOTAL	229,620	172,140	214,380	250,230	238,690	230,030	194,370	61,470	71,300	36,075	25,230

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[1] Compiled from data published by the U. S. Dept. Agriculture:
Reference 53. - 1947, p. 174; 1948, p. 187; 1949, p. 186; 1950, p. 188; 1951, p. 175.
Reference 55. - August 1, 1951, p. 55; August 1, 1952, p. 52.

[2] Other Western States, i.e., Montana, Idaho, Colorado, Utah.

Table 7.-*U. S. production and utilization of cherries for the period 1946 - 1950*[1]
[*Cherry pits, wet basis, represent 8 percent of the fresh fruit; dry basis, 4 percent*]

Year and Type		Production	Fresh and farm house-hold use	Commercial Utilization				
				Canned	Frozen	Brined	Others	Total
		Tons	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
1946	Sweet	112,370	43,200	30,320	5,390	30,920	1,540	68,170
	Sour	117,250	15,930	55,920	44,010	490	850	101,270
1947	Sweet	79,270	42,180	10,410	660	24,880	60	36,010
	Sour	92,870	14,640	40,570	35,490	980	600	77,640
1948	Sweet	79,620	33,210	15,800	710	29,710	20	46,240
	Sour	134,760	17,520	66,900	46,290	3,550	500	117,240
1949	Sweet	137,700	59,460	27,120	800	40,790	130	68,840
	Sour	112,530	17,680	57,790	35,280	1,440	340	94,850
1950	Sweet	82,050	39,829	11,711	370	29,970	-	42,051
	Sour	156,640	17,710	87,765	52,925	1,350	100	142,140

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[1] Compiled from data published by the U. S. Dept. Agriculture:
Reference 53. - 1951, p. 174.
Reference 55. - August 1, 1952, p. 52.

Table 8. *Production and utilization of cherries by areas for the year 1950*[1]
[*Cherry pits, wet basis, represent 8 percent of the fresh fruit; dry basis, 4 percent*]

Type and Locality	Production	Fresh and Farm household use	Commercial Utilization				
			Canned	Frozen	Brined	Other	Total
	Tons	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
Sweet							
Great Lakes States	14,910	4,270	1,130	250	8,160	-	9,540
Washington-Oregon	33,900	16,690	4,460	70	13,780	-	18,310
California	31,000	17,250	6,000	50	7,700	-	13,750
Western States	2,240	1,619	121	-	330	-	451
Total	82,050	39,829	11,711	370	29,970	-	42,051
Sour							
Great Lakes States	148,360	13,750	85,550	50,100	1,350	50	137,050
Western States	8,280	3,960	2,215	2,825	-	50	5,090
Total	156,640	17,710	87,765	52,925	1,350	100	142,140
TOTAL	238,690	57,539	99,476	53,295	31,320	100	184,191

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[1] Compiled from data published by the U. S. Dept. Agriculture:
Reference 53.- 1951, p. 175.
Reference 55.- June 10, 1952, p. 22; August 1, 1952, p. 52.

Table 9. *Annual production of peaches for the period 1946 - 1951, by States*[1]
[Peach pits, wet basis, represent 8 percent of the fresh fruit, dry basis, 4 percent]

State	Annual Production					
	1946	1947	1948	1949	1950	1951
	Tons	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
Arkansas	59,496	53,280	59,568	57,888	39,600	25,056
California	890,064	792,072	723,048	845,064	712,056	861,072
Colorado	47,640	50,544	46,128	50,616	29,256	7,584
Georgia	135,072	139,440	67,488	48,960	19,440	95,400
Illinois	36,696	57,912	34,272	55,368	32,256	5,376
Michigan	122,400	103,200	78,000	84,000	115,200	14,520
Missouri	26,352	30,912	18,048	22,800	12,000	7,296
New Jersey	42,624	38,808	28,200	46,752	40,896	47,808
New York	40,368	34,560	26,736	34,272	24,552	31,488
North Carolina	75,840	69,720	39,504	34,272	7,776	43,344
Ohio	13,272	24,480	18,720	28,656	19,392	21,768
Oregon	17,496	20,424	14,280	23,496	6,000	9,600
Pennsylvania	53,424	46,080	52,368	58,824	52,656	56,448
South Carolina	143,856	159,120	75,840	56,160	8,650	119,520
Texas	44,544	40,704	27,360	57,600	11,328	16,704
Virginia	63,360	40,320	29,016	41,616	16,968	42,504
Washington	64,800	67,608	53,040	66,528	3,240	19,440
Total, U S	2,079,432	1,974,480	1,568,448	1,795,632	1,151,266	1,424,928

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[1] Compiled from data published by the U S Dept Agriculture:
Reference 53 - 1951, p. 195.
Reference 55 - October 10, 1951 p. 47; June 10, 1952, p. 18; August 1, 1952, p. 47

Table 10. *U. S. production and utilization of peaches for the period 1946 - 1951*[1]
[Peach pits, wet basis, represent 8 percent of the fresh fruit; dry basis, 4 percent]

Year	Production, U. S. Total	Farm household use and fresh	Commercial Utilization				
			Canned	Dried	Frozen	Other	Total
	Tons	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
1946	2,079,432	1,252,560	613,176	163,320	36,648	4,704	817,848
1947	1,974,480	1,204,776	603,360	111,408	17,544	1,632	733,944
1948	1,568,448	932,808	568,944	52,992	9,600	792	632,328
1949	1,795,632	1,005,144	545,760	93,312	14,928	1,104	655,104
1950	1,283,640	660,136	485,256	47,592	18,264	-	551,112
1951	1,678,368	-	-	-	-	-	-

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[1] Compiled from data published by the U. S. Dept. Agriculture; Reference 53 - 1951, p. 197.

Table 11.-*Production of threshed peanuts for the period 1946 - 1951, by States, and quantities used on the farms, used as seed, and exported*[1]
[Peanut shells represent 33 percent of the whole peanut]

State	Annual Production					
	1946	1947	1948	1949	1950	1951
	Tons	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
Alabama	129,800	145,845	177,355	145,250	162,680	102,810
Arkansas	1,687	1,400	1,800	1,800	1,662	1,610
Florida	23,250	34,650	42,625	25,627	29,520	31,320
Georgia	358,450	390,590	409,150	306,000	339,937	297,900
Louisiana	560	750	502	540	510	487
Mississippi	2,625	2,437	3,000	2,437	2,762	1,500
New Mexico	4,100	6,650	4,590	3,850	3,272	3,010
North Carolina	136,437	150,380	173,312	121,540	123,007	157,605
Oklahoma	58,565	73,125	76,500	56,950	62,640	57,200
South Carolina	8,450	7,150	9,100	7,150	7,900	5,670
Tennessee	2,125	2,000	2,000	2,062	2,000	1,400
Texas	197,502	177,650	150,400	166,725	161,700	59,150
Virginia	95,625	98,820	118,900	97,980	112,055	118,400
Total, United States	1,019,177	1,091,447	1,169,235	937,912	1,009,647	838,062
Farm use excluding seed	29,938	29,052	27,848	26,207	26,673	-
Seed	122,600	113,830	89,530	88,630	84,248	-
Net exports	124,728	265,913	319,633	121,432	-	-

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[1] Compiled from data published by the U. S. Dept. Agriculture.
Reference 53.- 1948, p. 146; 1949, p. 141; 1950, p. 143; 1951, pp. 131, 133.
Reference 55.- November 9, 1951, pp. 12, 29; August 1, 1952, p. 42.

Table 12 *Annual production of pecan nuts from improved varieties and seedling of pecan trees for the period 1946 - 1951, by States*[1]
[*Shells represent 62 percent of whole nut for seedling varieties, 58 percent for improved varieties*]

States	Annual Production											
	1946		1947		1948		1949		1950		1951	
	Improved Varieties	Seed-lings	Improved Varieties	Seed-lings	Improved Varieties	Seed-lings	Improved Varieties	Seed-lings	Improved Varieties	Seed-lings	Improved Varieties	Seed-lings
	Tons	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
Alabama	3,321	1,049	3,087	632	8,250	1,750	6,350	1,400	5,450	1,150	10,650	2,350
Arkansas	125	475	327	1,598	545	2,325	325	2,125	200	1,025	400	2,275
Florida	1,325	938	835	552	1,505	1,232	1,040	785	1,600	1,000	1,720	920
Georgia	6,500	1,500	11,766	2,076	16,250	3,550	7,200	1,800	16,750	3,750	21,150	4,600
Louisiana	1,125	3,375	700	1,500	2,350	7,150	1,100	7,400	550	4,000	1,725	6,125
Mississippi	960	1,215	652	797	2,200	2,550	2,250	2,750	815	997	3,500	3,300
N. Carolina	612	60	867	153	1,225	151	1,286	175	921	102	1,095	123
Oklahoma	550	2,950	1,550	20,450	500	6,500	1,020	10,980	315	3,185	750	11,750
S. Carolina	590	113	1,100	175	1,550	250	1,375	225	1,275	225	1,840	325
Texas	1,700	9,550	1,500	8,950	3,400	25,100	1,740	12,760	1,000	18,500	500	2,350
Total, U. S.	16,817	21,535	22,435	36,884	38,275	50,558	23,686	40,400	28,876	33,934	43,330	34,118

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[1] Compiled from data published by the U. S. Dept. Agriculture.
Reference 53. - 1946, p. 280; 1947, p. 272; 1948, p. 289; 1949, p. 298; 1950, p. 300; 1951, p. 279.
Reference 55 - November 9, 1951, p. 37; August 1, 1952, p. 52.

years to illustrate the extent that growing conditions cause yields to fluctuate. These figures are presented also by states to assist in evaluating the supply of pits or shells in given areas. The figures further show the quantity of the crops sold fresh, canned, dried, or processed in any other manner. The conversion factors already shown in table 3 can be applied to the appropriate data in the tables to estimate the supply of any one or more of the shells or pits. Over 2 billion pounds of all shell residues are produced annually.

Availability

Of the quantity of shells and pits produced each year, a considerably smaller amount actually becomes available for commercial processing. This results from a number of factors: (a) Materials used on the farm where grown, either as fresh fruit (nuts), by canning, or as seed; (b) material sold fresh or unshelled without processing; (c) location is not conducive for shipping to processing plants; (d) volume of waste at cannery or cracking plant too small for practical consideration; and (e) culls or unharvested crop.

Canneries, cracking, drying, freezing, and other packing plants become the logical sources of these residues. Surveys of areas (other than those on the West Coast) in which black walnut shells and peach and cherry pits accumulate and are available in significant quantities have been made. For some states in which accumulations are appreciable, the data are presented in table 13. Based on the fact that continuous year-round operation (one shift) of shell-grinding plants requires 5,000 tons of shells, it is readily apparent that, in some areas, the quantity of shells or pits available is insufficient for consideration, or that more than one kind of shell will be needed.

DISPOSITION OF SHELLS AT CRACKING PLANTS

The problem of disposing of shells accumulating from nut-cracking operations may be dealt with in one of several ways depending upon the physical and chemical characteristics of the residue. Frequently the shells are burned as fuel in the plant boilers. This practice reduces the expense of power consumed. However, in plants where large quantities of shells accumulate, the supply may exceed fuel requirements, so that burning this surplus in the boilers might increase operating and maintenance expense.

Shells are often discarded on a dump or used for ground fill. This, too, involves an expense which must be considered when calculating the economics of any other use or processing.

Industrial processing of shell wastes frequently affords a profitable means for disposing of nut shells. Where processing is to follow cracking, the size of processing operations can be geared to handle the major portion of the waste material; thus, facilities for storing raw material can be kept at a minimum. However, when processing demands are greater than the supply of shells from a plant, the local shells must be augmented by like material obtained from other cracking plants. When such a condition exists, facilities must be provided for unloading, short-term storage, and cleaning prior to processing.

Table 13.-*Approximate quantities of cherry pits and black walnut shells available annually from commercial processing in certain states, by Counties*[1]

State and county	*Tons*	State and county	*Tons*
Cherry Pits			
Michigan:		New York:	
Allegan	500	Chautauqua	10
Antrim	300	Columbia	10
Benzie	375	Monroe	150
Berrien	300	Niagara	45
Charlevoix	40	Ontario	40
Grand Traverse	1,100	Orleans	15
Leelanau	400	Wayne	190
Manistee	75		
Mason	150	Pennsylvania:	
Sanilac	20		
Oceana	625	Erie	60
Van Buren	175		
		Wisconsin	
		Door	1,025
Black Walnut Shells			
North Carolina:		Tennessee:	
Cherokee	125	Davidson	2,750
		Hamblen	1,250

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[1] These values have been compiled from information furnished in private communications from fruit processors and nut crackers.

Crackers of pecans find some demand for their shell refuse (which includes meat fragments, shell liners, and septa) in plants recovering oil and tannin. The situation is somewhat similar for walnut shells in that the shell refuse is sent to plants for recovery of the oil from the meat fragments before the shells are processed.

DISPOSITION OF FRUIT PITS AT CANNERIES AND PACKING PLANTS

The problem of disposal of fruit pits at canneries and fruit-packing plants differs to some extent from that for nut shells.

Fruit pits, as they become available, are generally in a wet condition. The pits may also have some residual fruit flesh or pulp remaining on their surfaces. Often these pits are ground to fine particle size in a hammer mill and the product flushed into the sewer. This operation is analogous to that of dumping nut shells and is fairly expensive. This disposal expense may be included as a credit when the pits are being considered for other processing.

In canning and packing fruits, such as peaches, the fruit is often halved by sawing. This operation, although releasing the kernels from the shells, also mashes the kernels so badly that separation and recovery of shells or pits by preferential flotation in brine is difficult. This difficulty has tended to discourage the use of peach pit kernels as a source of oil. The shells are used by processors who convert them to charcoal or grind them for industrial purposes. In many cases, no separation of kernels from shells is made prior to disposal of the shells to a processor, the separation then being a job for the custom processor. Large quantities of whole pits are still available for oil recovery in many sections of the country.

Custom grinders of pit shells frequently install pit-cleaning equipment at the fruit canneries. The pits are cleaned, washed, and drained before loading into freight cars or trucks. This eliminates similar operations being repeated at the grinding plants. Also transportation of large quantities of residual fruit pulp is avoided. No pits accumulate on the cannery site when this method is practiced.

Cost

The cost of unground shell materials and fruit pits depends upon: (a) The source of the materials; (b) value as power-plant fuel; (c) condition at points of accumulation; (d) distance to be transported to processing sites; and e) storage facilities required. How much a grinder can afford to invest in procuring and processing such raw materials depends upon the price the consumer will pay for the finished products.

The cost of shells or pits to grinders is sometimes considered as their value as fuel, this value being approximately one-half that of coal. Where a grinding installation processes shells or pits from a single-cracking or canning operation, the fuel value of these residues may be charged against the products. Grinders who purchase shells and pits from cracking plants or canneries where these residues are used as fuel, should expect to pay at least the fuel value.

Excessive moisture and contamination of shells or fruit pits by refuse, such as kernels, kernel fragments, shell liners, septa, alter the initial value of the shells. Although the presence of kernels and meat fragments necessitates additional steps in processing, they may actually increase the value of the pits and shells because of their oil content. Liners and septa from pecan shells have value for their tannin content. Excessive moisture detracts, however, from the value of the raw materials, since this moisture must be removed during processing in order to insure quality products. Raw materials, if purchased, should be procured on the basis of a definite moisture content.

Transportation of raw materials to grinding sites may result, in some instances, in excessive costs. The bulk weight of the materials involved must be considered. In general, nut shells and fruit pits are sufficiently dense to make shipping or hauling over reasonable distances permissible. Some processors of apricot pits can afford to procure these materials from areas within a 40-mile radius of the plants. Materials such as peanut shells may require baling in order to reduce their bulk for shipping. Packaging is an additional expense which must be considered along with transportation costs.

The geographic location and general climatic conditions of an area within which a shell-processing plant is located influence the manner in which raw shells or pits may be handled. In areas where rain or snowfall is infrequent, open storage is satisfactory. Such storage may even be of benefit as residual meat and kernel fragments can deteriorate or be eaten by insects. Deterioration of the shell proper is negligible. In areas of excessive moisture, protection against darkening is desirable because ground products of light-color are preferred. Raw materials to be placed in storage should have a moisture content of less than 25 percent to avoid heating. Storage facilities should provide ventilation so that moist materials can dry out prior to use. Because some of the fruit pits and shells must be collected within a very limited period during the harvest and canning season, close attention must be given to the storage problem. The volume of materials that must be stored may make sheltered storage prohibitive.

To the custom grinder of fruit pits and nut shells the cost of the raw materials represents an accumulation of charges just discussed. The net result may be a cost ranging from $3 to $15 per ton for material delivered to the plant and ready for grinding.

AGRICULTURAL USES

Animal and Poultry Litters

A large volume of both almond and peanut shells is used for poultry litter. Peanut-shell litter has been rated very highly by poultrymen at the Delaware State Agricultural Experiment Station *(50)*. Almond shell litter was not included in those studies because emphasis was on materials readily available to the broiler areas of Maryland, Delaware, and Virginia. The highly absorbent character of these materials favor their use for keeping poultry house floors dry. Baled peanut shells are shipped more than 500 miles by rail into eastern and midwestern markets in competition with corncobs, dusted sugarcane bagasse, vermiculite, and other materials for this use. Poultry litter of this type can be used for many months by periodic additions of fresh material to the 4 to 5 inches initially spread. The shell material should be larger than 1/4 inch and dust-free.

Animal and Poultry Feeds

Emergency feedstuffs for livestock used in Germany during World War I included press cake from walnuts together with the shells *(30)*. Hulls from almonds have received some attention in this country as a feeding material *(4, 22)*. Generally, the hulls and shells are poor substitutes for the usual stock feeds.

Charcoal prepared by destructive distillation of nut shells and fruit pits is used in poultry and animal feeds *(28)*.

Mulch

Large quantities of shells from peanuts, almonds, pecans, and filberts are used as mulch. For this purpose, the fines (less then 1/4 inch) and light fractions are removed to prevent undesirable packing and to avoid the nuisance of the lighter materials being blown around the neighborhood. The use of these mulching agents conserves moisture for the plants and helps check weed growth. Competition from sawdust and wood chips, corncob products, sugarcane bagasse, vermiculite, and other agents will be encountered in various areas.

Fertilizers

A large amount of shell material from almonds and peanuts is being ground for mixing with commercial fertilizer to provide bulk, retard caking, and improve free-flowing characteristics in such products.

Ground products from shells of almonds, peanuts, and pecans are sometimes used as soil conditioners. Because the microorganisms that decompose these materials to humus require nitrogen, some nitrogen-carrying compound such as ammonium sulfate, liquid ammonia, or ammonium nitrate must be added to promote rapid decay and conserve the nitrogen already in the soil for the growing crop or the crop to be planted. Allison and Anderson discuss conditions under which wood sawdust can be used as a soil conditioner *(6)*. These conditions are also applicable to shell materials.

Insecticides and Pesticides

Frequently as little as 1 percent or less of the active ingredients of insecticides, fungicides, or herbicides, is needed in the finished commercial product. Dilution is necessary so that the user may obtain uniform and maximum coverage at a minimum of expense and without the danger of applying an overdose. Although working dilutions are sometimes obtained by adding water, often the particular ingredients may not be compatible with water, or the use of a liquid is otherwise not desirable. Under such conditions dusts of botanical origin are either necessary or preferred.

The carrier or diluent should be free of objectionable flavor and color, and without toxicity to humans and warm-blooded animals. The finished carrier should be a free-flowing powder that is devoid of lumps or stickiness. At least 99 percent of the material should pass a U. S. Standard No. 60 sieve by dry-shaking, and have a "surface mean particle diameter" of not more than 10 microns when tested by the air-permeation method.[6]

Flour from walnut shells is being used successfully in dusting materials. Flours from other nut shells and fruit pits have been investigated in wettable preparations of 50 percent DDT.[7] The excessive foaming encountered with the botanical powders when used in suspensions can be overcome by additions of antifoam agents and by blending with mineral diluents. A manufacturer of protectant dusts for stored grain has found flour prepared from corncobs satisfactory as a filler or a diluent for the active ingredients.[8]

Miscellaneous Uses

Shells of nuts and fruit pits are often used for fill on low ground or for correcting conditions of poor drainage. Both measures aid in reducing soil erosion.

Broken or coarsely ground shells of the harder varieties are used to cover walkways and driveways instead of crushed rock or gravel.

Shells of some nuts have been used to produce smoke in curing meats. The shells are allowed to smoulder thus developing a dense smoke.

INDUSTRIAL USES

Uses Based on Physical Properties

FUR CLEANING

For many years corn meal has been used for cleaning furs. The demand for non-edible materials as fur cleaners led to the use of sawdust from hard maple wood and likewise, during the past 20 years, to the use of the woody portion of corncobs. Cobs used for this purpose are ground and classified to about No. 12/20, the beeswing, dust, and chaff being removed by aspiration. In recent years, improvements in fur-cleaning machinery have made it possible to extend the classification to sizes ranging from No. 8 to No. 100; the actual classification preferred, depending upon the particular machinery in use. Also, ground products of nut shells and fruit pits are now being used in large volume for this purpose. Size classification for the shell or pit materials is similar to that for the cob products. Some furriers prefer the shell products, claiming that the small amount of oil present in the shells is beneficial in cleaning.

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[6] Memorandum from R. C. Roark, Bureau Entomology and Plant Quarantine, U. S. Department of Agriculture, Beltsville, Maryland, February 28, 1951.

[7] Unpublished data, R. C. Roark and E. F. Knipling, Bureau Entomology and Plant Quarantine, U. S. Department of Agriculture, Beltsville, Maryland, March 31, 1950.

[8] Private communication from F. D. Berlin, U. S. Industrial Chemicals, Inc., Baltimore, Maryland, January 29, 1951.

SOFT-GRIT BLASTING

During World War II the Northern Laboratory, in cooperation with the Navy, developed a process for removing carbon, oil, and products of corrosion from cylinder heads, pistons, valves, and other parts of aircraft engines. The process consisted of air-blasting the parts with cob grits or mixtures of cob grits and rice hulls *(32)*. During the same period the Army Air Forces used grits from shells of walnuts and apricot pits in a similar manner. The Northern Laboratory subsequently made comparative tests of soft grits, No. 12/30, derived from a number of shell materials and corncobs *(19)*. Shells of almonds, apricot pits, cherry pits, coconuts, filberts, peach pits, pecans, black walnuts, and English walnuts were included in this investigation.

The rate of penetration of paint films baked on steel panels by blasting with shell grits was roughly in the order of the hardness of the grits; penetration rates and durability of soft grits, as measured by dust formation, are shown in table 14. With the exception of grits from cherry-pit shells, the amount of dust formed and removed from the blast booth in 1 hour was about the same for the various grits, usually about 2 percent of the original grits. Nearly 40 percent of dust was obtained from the cherry-pit shells in the same period. The reduction to particles finer than No. 30 during 1 hour of blasting was generally greater for the hard, friable shells than for the softer varieties, such as from filberts, pecans, and English walnuts. This reduction is not serious because grits as fine as No. 50 are still very effective in blast cleaning.

Table 14.--*Rate of penetration of baked on paint films by soft grits, and dust formation during 1 hour of blasting at 90 p.s.i*

Type of shell grits	Penetration time, seconds		Dust formed
	Grits only	Grits plus rice hulls	
			Percent
Black walnut	4	4	1.4
Coconut	4	4 1/2	3.7
English walnut	5	5	2.9
Peach pit	5 1/2	5 1/2	1.7
Pecan	5 1/2	7	1.2
Filbert	6 1/2	5 1/2	1.3
Cherry pit	7	3	39.7
Hard-shell almond	9	7	2.9
Soft-shell almond	9	7 1/2	2.1
Apricot pit	11 1/2	7 1/2	6.2

Rice hulls added to soft grits usually accelerate the cleaning action because of the abrasive character of the rice hulls. This characteristic results from the 18 to 20 percent of silica bound chemically in the structure of the rice hulls. The abrasive action is not sufficient to cause dimensional changes or removal of metal; hence, one reason for the effectiveness of the soft-grit method in cleaning precision-finished machine parts. The effects of additions of rice hulls to soft grits on penetration rates are also shown in table 14. In all cases the proportion of soft grits to ricehulls was 9:5 by weight.

Use of the soft-grit method has resulted in considerable savings in man-hours of labor as well as in salvage of many machine parts which otherwise might have been junked. Four to 10 times more work is accomplished by this method than by older methods of soaking and scraping. The method is almost foolproof after soft grits and operating conditions have been properly selected. No highly skilled operators, no masking, or hand tools are required.

The method has the added advantage of eliminating hazards of fire and personnel injuries associated with solvent methods of cleaning. Chlorinated solvents frequently are very toxic, and their improper use has accounted for a number of fatalities in industrial cleaning *(12, 29, 40)*.

In the soft-grit method, parts to be blasted may be degreased first if the oily material adhering to the parts is excessive. Then, induction- or pressure-tank-type blast units may be used, the selection depending upon the size and nature of the pieces to be cleaned. In the induction or booth-type unit, the grits are recovered continuously and recirculated until worn out or become contaminated excessively with oils and greases. Grits are contained in a hopper beneath the booth and fall by gravity to an induction chamber from which they move by suction to the blast nozzle. Spent grits drop through a grating or screen within the booth to the storage hopper. Air pressure of 80 to 90 pounds per square inch is required for satisfactory blasting.

Small blast units suitable for use in neighborhood service stations, small shops, and in large industrial plants are readily available.

During World War II one large distributor of automobiles and trucks stated that his firm was able to retain its position in the spare-parts business only through salvage by the use of the soft-grit cleaning method. Since about 1945, the Northern Laboratory, in cooperation with industry, has developed a wide variety of civilian uses for soft grits. Many large companies that rebuild automotive engines are using the soft-grit method as a routine procedure. The rubber industry has found the method useful in cleaning and maintaining molds for hard rubber and in cleaning the tread molds used in manufacturing and recapping tires. Glass manufacturers, in addition to cleaning molds and core boxes, use shell grits for surface finishing of hardened steel molds of intricate design and of critical dimension. Automobile manufacturers use soft grits for finishing precision parts such as those in automatic transmissions and torque converters.

Rust, water scale, carbon deposits, oils, waxes, and other foreign material are easily removed from iron, steel, brass, aluminum alloys, and similar metals by the soft-grit method. The method is not a means for developing polished surfaces, since a matte finish results from blast-cleaning. Automobile lacquers and paints on metal surfaces are removed effectively. Glazed enamels and porcelainware are unaffected so that such materials can be blast-cleaned safely. Mill scale on steel is not removed by this method.

The soft-grit blast method has been extended to the finishing of molded plastics and hard rubber parts. Flash and fins along parting lines are removed from the molded pieces without harm to the molded surfaces if air-blasting is done with soft grits classifying as small as No. 50. Such cleaning can be done in a continuous operation and production is much greater than can be achieved by hand finishing.

Soft grits for blast-cleaning operations are prepared in commercial quantities in sizes ranging from No. 10 to No. 50. Specific job requirements limit the classifications to closer particle sizes. Classified grits must be free of foreign substances such as pit kernels, lining materials, splinters and dust. Typical size specifications for soft-grit blasting material from shells are given in table 15. According to Army Air Force specifications, specific gravity of the particles as determined by a sink-or-float method should range from 1.28 to 1.40. For general use, the lower limit on specific gravity may be reduced somewhat.

Table 15.-*Typical size classification for soft grits for air-blast use*

Type of Work	Sieve Sizes, U. S. Standard
General purpose	No. 12/30
Heavy duty	No. 12/16
Detail work	No. 16/25 or No. 16/30
Plastics	No. 16/25 or No. 25/40

DEBURRING, BURNISHING, AND POLISHING

Tumbling methods of product finishing include the removal of burrs from the edges of metal stampings, the removal of flash and fins from molded plastics, hard rubber, and metal die castings, and the burnishing and polishing of these items. For a number of years hardwood sawdust, and wood chips, pegs, and balls, as well as a wide variety of small metal shapes or jacks, were used for such finishing operations. Prior to World War II, a small volume of ground corncob material was being used in metal finishing. As the military requirements during the early 1940's increased, more cob material was produced to meet the demands. Later it was found that ground products from the shells of nuts and fruit pits were also well adapted to metal finishing.

Manufacturers of metal-finishing equipment have been alert in modifying their machines to meet the changes brought about by the use of these new soft-grit blasting materials. One manufacturer of molded plastics and metal die castings for precision instruments uses dry-tumbling equipment in which soft grits (apricot pit shell) are thrown, by a paddle-type wheel, at the material to be deburred and finished. This manufacturer states that his company is saving $100,000 annually through use of the shell grits by this method *(13)*. Grits from apricot-pit shells were selected for this application because of their low content of oils and waxes which otherwise would cause a "blush" or "bloom" on the finished articles.

Grits for deburring are often used wet in conjunction with fine abrasives such as emery or silicon carbide. Particle size of the grits might be as large as 1/4 inch, but in general the size is limited in the range from No. 8 to No. 50, the actual limits depending upon the surface detail of the objects being deburred.

For these applications the grits should be angular in shape, dust-free, and devoid of contaminants such as chips, stones, and iron or steel. Grits used for polishing operations are generally finer than No. 16 and may be as fine as No. 60. For burnishing, slightly coarser particles, for example, No. 8, are usually the largest particle size used.

HAND SOAPS

Immediately following World War II, when conservation of foodstuffs was still emphasized, manufacturers of hand soaps sought assistance of the Northern Laboratory in finding a replacement for the corn meal used as a mild abrasive. Studies made at the Laboratory showed that corncob meal free of chaff, pith, and beeswing was a satisfactory abrasive in powdered soaps *(17)*. Although a light color is usually preferred, the techniques used in manufacture of the soap, masks the color of the abrasive fillers. Light-colored meal from nut shells and fruit pits has been suggested as an abrasive for this use. The shell meal would probably classify as No. 50/80 or No. 50/100 for this application.

BRICKS, CERAMICS, AND CLAY PRODUCTS

For the control of porosity in bricks and ceramic ware, the ground products of nut shells and fruit pits are excellent. The ground materials of desired particle size are included in the formulations and when the clay products are fired the woody material (lignocellulose) burns out, leaving the product with a porous structure. The particle size of the ground materials depends upon the end use of the ceramic products.

FILLERS

Plastics.--Finely ground shells of most nuts and fruit pits are excellent materials for use as fillers in phenolic molding compounds. The Northern Laboratory, realizing a need for information on this subject, conducted extensive investigations *(18, 60)* with 22 agricultural residues of which 12 were shells of nuts and fruit pits. The harder types of shells are less absorbent and, consequently, the resin content of the experimental compounds could be reduced below normal without loss of molding and physical properties.

At about the same time, Patronsky at the University of Michigan, cooperating with the Tennessee Valley Authority, studied the use of flour from black-walnut shells in phenolic molding compounds *(44)*. Results of physical tests on the molded products are similar to those obtained at the Northern Laboratory.

Flours for use in plastics molding compounds should be finer than No. 100. Some compounders of plastics prefer flours finer than No. 200, and even as fine as No. 325. These finer grades of flour filler impart superior surface characteristics to the molded products. The lighter-colored flours are preferred because of the economy and ease with which dyes and pigments can be incorporated into the compositions. To obtain light-colored flours only the inner woody portion of most fruit pits and nut shells should be used. The dark outer surfaces, together with lining material and septa, should be removed in grinding and classifying operations. In some cases, as with pecan shells, tannins which are concentrated in the inner linings and septa are interfering substances. Kernel residues and nut meat fragments likewise interfere with the use of shell flours in plastics compounds because of the oils and waxes present. Some processors of shells and pits expose the incoming stock to weathering during which time worms and other small organisms consume the kernel and meat residues. These organisms are removed by screening and aspiration prior to grinding operations.

Van der Pyle claims in a 1943 patent that molded articles can be made by hot-pressing ground walnut shells without the addition of resinous binders *(58)*. It is claimed that walnut shells contain all the necessary bonding materials and properties.

Ground nut shells are used in various plastic-like coating preparations as anti-slip agents for walkways, steps, and decks. In a patent, Patch *(43)* claims formulations based on the use of ground walnut shells in aqueous dispersions of natural or synthetic rubber for similar applications.

Structural board materials of the granular type prepared from peanut shells have been investigated by Williamson and Lathrop *(62)*. Two possible methods of manufacture were studied: (a) High temperature treatment of ground shells mixed with vinsol;[9] and (b) hot-pressing of ground shells mixed with phenolic resins and pine gum. Neither process appears economically feasible in competition with processes using sawdust, shavings, or other wastes of wood-processing industries.

Many other publications discuss the use of nut shells, particularly those from English walnuts, in plastics compounding and manufacture *(1, 23, 25, 26, 38, 42, 49, 51)*.

Plywood Adhesives.--The manufacture of plywood and laminated timbers for structural purposes requires large quantities of glues or adhesives. Synthetic resins initially used only for exterior and marine-grade products are now being used in the manufacture of interior structural boards. In order to compete with animal glues and casein products, the more expensive resins are diluted or extended with low-cost fillers.

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[9] Low-priced resinous product obtained from pine wood pitch. Melting point, about 240° F.

Williamson and Lathrop have reported results of investigations on flours from a variety of agricultural residues as extenders in plywood resin glues *(61)*. Savings in resin usage ranged from 21 to 41 percent for the shell flours studied. In all cases, dry-shear strength was greater for the extended glues than for the glues alone. Wet-shear strength, following 3-hour immersion in boiling water, was only 16 percent (maximum) less for the extended glues than for the resin glues alone. These strength values still exceed minimum requirements of Army and Navy Specification AN-P-69a. Although the flours for use as extenders usually pass a No. 200 sieve, it was also shown that material as coarse as No. 40 had strength properties equal to or surpassing glues containing No. 200 flour.

Olson and Soper at the Forest Products Laboratory in an unpublished report to the Tennessee Valley Authority compared flours from English and black-walnut shells as fillers for resin glues *(42)* Urea-formaldehyde and resorcinol-formaldehyde glues were used in those studies. No consistent differences between the two flours were observed. The authors concluded that flour from black-walnut shells could be used just as satisfactorily as an extender for plywood adhesives as flour from English-walnut shells.

Rubber Compounding.--In molded hard-rubber goods, fillers of both organic and inorganic origin are used to reduce costs, control specific gravity, and impart definite characteristics to the molded products. In some cases resistance to certain chemicals is necessary. Rubber compounds, for example, those used in storage battery boxes, are formulated to include ground products of nut and fruit pit shells, both being resistant to the sulfuric acid used in storage batteries. Particle size requirements vary over a wide range but materials classifying finer than No. 60 are used most frequently in hard-rubber compounds.

Automobile and Tractor Tires.--Superior traction and nonskid properties are incorporated into automobile and tractor tire treads by the inclusion of relatively coarse particles (No. 8/30 for example) of hard shells or corncobs in tread stocks. A patent has been granted on the use of corncob particles as the grit in tread stocks *(45)*. The products usually considered as "snow tires" have proved very satisfactory not only on wet pavements but on ice and snow. Two ideas have been advanced to explain the effectiveness of snow tires: (a) The abrasive action of exposed grits and (b) the "vacuum cup" resulting from cavities arising when grits are removed during wear from the surface of the tread. The latter idea appears to be generally favored by individuals in the tire manufacturing business.

Cork Substitute.--About 300,000 tons of natural cork are used annually in the United States for liners in crown seals. These seals are used for bottled carbonated beverages, beer, fruit juices, catsup, and other liquid or semiliquid preparations. Early in World War II, when the use of cork was subject to rigid government control, bottlers appealed to the U. S. Department of Agriculture for materials to replace natural cork. Research at the Northern Laboratory resulted in the development of "Noreseal" compounds for such crown seal use *(8, 9)*. The compounds could be made available in paste, sheet, or rod form. They were tested exhaustively with close cooperation of commerical bottlers. More than 7,000 service tests, covering periods up to 5 years, made with Noreseal compounds showed that this cork substitute met service conditions equally well as compared with crown cork seals.

The pith material found in many agricultural residues, including peanut shells, had been suggested as cork substitutes. The large air cells and the thin cell walls were not suitable for their direct use. However, finely cut pith particles could be incorporated into a fluid composition that set and hardened to an elastic mass with characteristics closely resembling those of cork. More air cells could be incorporated into the composition by "whipping." A representative formulation for Noreseal, made with ground peanut shells, is given in table 16. One of the pilot-plant studies on this research conducted at Peoria, Illinois, was financed by a leading beverage manufacturer on behalf of a national trade association. Two patents covering methods for producing cork substitutes have been granted to Lathrop and Aronovsky *(33, 34)*, and a patent covering the use of cork substitutes in crown closures to Aronovsky *et al. (10)*.

Table 16.-*Representative composition of Noreseal compounds*

Substance	Parts by Weight
Glue or gelatine	100
Glycerine	75
Glucose	75
Ground peanut shells	100
Water	350
Saponin or sulfonated hydrocarbon	11-21
Formaldehyde	2

FOUNDRY APPLICATIONS

The use of ground-shell products in foundries is a specialty application, small in tonnage as compared to other uses for processed shell. Foundry use requires extremely fine flours; No. 325, or finer, as replacements for plumbago and lycopodium which are used as dusting compounds for the interior of sand molds and as mold-parting compounds. Burning of the shell material during the pouring of a melt results in a gaseous cushion between the molten metal and the molding sand. The resulting castings, whether ferrous, aluminum, or bronze have smoother surfaces than would be possible otherwise.

WOOD FINISHING

In the woodworking industries, particularly in furniture manufacture, improved mechanization of operations in the mill room has been the general practice. Finishing operations, however, have continued to be laborious and time consuming. Conveyors and automatic spray-gun equipment installed in some plants have reduced finishing time slightly, but much of the hand labor involved is the same as required 100 years ago. Lehman reports that to avoid use of expensive stains, which frequently are grain-raising, to eliminate the toning operations, and to use lumber of mixed color, dry pigments carried by fine grits from nut shells or fruit pits, sand, or metal can be air-blasted at low pressure on to sanded wood surfaces *(36)*. This staining and finishing method is claimed from actual records to require less than 1/4 the time for the customary staining and toning operations; less than 2 minutes as against a total of 9 minutes.

The process is carried further to produce uniform grained finishes without resorting to bleaching of the woods. Discolorations, sap stains, and mineral streaks are completely obliterated. In this process a thin opaque coat of white is applied to the surface and dried before blasting with the pigment and shell grits.

In both phases of finishing by blasting with dry pigment and grit mixtures, the amount of pigment is about 0.5 percent by weight of the carrier. No stain is lost through evaporation of solvents, or by the use of wiping rags. The unused pigment accumulating in the blast booth may be recovered with the grits and used after adjustment for proper concentration in the grits.

Dust-free, dense shell grits classifying in the general range of No. 40 to No. 100 are considered satisfactory for this use.

INDUSTRIAL EXPLOSIVES

Dynamite is manufactured for a wide variety of applications and, consequently, is prepared in sticks having definite concentrations of nitroglycerine. Nitroglycerine is a heavy, oily liquid and in such form has but limited application. For convenient handling, the liquid is mixed with absorbents, such as kieselguhr, sawdust, wood flour, or other porous materials. The explosive strength of dynamite cartridges is controlled by the amount of grits or meal prepared from corncobs, or shells of nuts and fruit pits, or wood added to the nitroglycerine. Particle size of these materials range from No. 10 to No. 100, the limits on classification being specified by the individual explosive manufacturer.

Uses Based on Chemical Properties

DESTRUCTIVE DISTILLATION

A wide variety of products, such as charcoal, gases, phenolic compounds, acetic acid, tar acids, and pitch, may be produced by the destructive distillation of nut shells, fruit pits, other agricultural residues and wood *(7, 14, 15, 21, 24, 27, 47, 52)*. The process has been of diminishing importance following World War I. Manufacture of the above chemicals from natural gases, coal, air, limestone, and water have been found more economical than the destructive distillation processes. A few plants continue to prepare specialty items by destructive distillation. High quality charcoal for use in case-hardening or heat treatment of steels by carburizing is obtained by the destructive distillation of dense shells from black walnuts, coconuts, English walnuts, pecans, and pits of apricots and peaches. Activated carbon prepared from black walnut shells is reported to be of excellent quality and very effective in hypersorption units purifying the constituents in natural gas. The carbon is also used as an absorptive agent in gas masks and industrial respirators. Shells which have been used for the preparation of charcoal and activated carbons *(39)* include those of black walnuts, coconuts, English walnuts, pecans, and pits of apricots and peaches.

CUTIN, WAXES, AND OILS

Shells of English and black walnuts and of filberts contain significant amounts of cutin which varies in color from pale yellow to practically white. Cutin is a wax-like material having many of the properties of the true waxes. It is possible that applications where such properties are required could be found if commercial methods for isolation and recovery of the cutin are developed.

Date stones or pits contain a substantial amount of oil that might have industrial significance if oil extraction is practiced prior to or during grinding of the pits for other purposes.

Processing of cherry pits, which as yet has not been practiced commercially, necessitates separation of the shells from the kernels. The oil of the kernels, comparable in quality and characteristics to the oils from other pit kernels, approximates 28 percent of the weight of the kernel. It might be worth determining if the value of the oil would be sufficient to defray the expense of separating shells from the kernels.

TANNINS

Very large tonnages of tannin materials are imported each year into this country for curing and tanning leathers and hides, and for the preparation of "muds" used during drilling of oil wells. Many materials of domestic origin are sources of tannin but not all the tannins obtained from them are suitable for use, and many of the sources are not sufficiently inviting for immediate commercial exploitation. The Eastern Regional Laboratory, Philadelphia, Pennsylvania, is continually investigating new domestic sources of tannins and their properties.

One company recovers tannins from the liners and septa of pecans by leaching with water *(2, 3)*. Pecan shells are included with the tannin stock, (liners and septa), so that packing of the stock in the extractor will not interfere with circulation of the water. The tannin stock contains about 30 percent of tannins while the content of the shells is less than 1 percent tannin. The leachings are concentrated until the tannin content reaches about 30 percent, and evaporation of water may be continued on drum dryers until a dry product is obtained.

A tannin free of gallic or gallotannic acid and a method for its production from pecan shells are claimed in a patent granted to Allen *(5)*.

A method for concentrating the tannin-bearing components in pecan and filbert shell wastes is claimed in a patent issued to Lathrop *(31)*. Shells are ground coarsely, for example, with a hammer mill having screen openings of 1/8-inch diameter, and then the product is aspirated to remove the light-weight lining materials and septa.

"Muds" used in drilling oil wells must act as drill lubricants as well as soil stabilizers and seam fillers. Tannins, together with other constituents in these "muds," function to meet the changing conditions of soil structure and composition. Formulations of the "muds" must be modified as soil conditions change.

FUELS

Nut shells have been used as fuel for the power house serving the cracking plant from which the shells are obtained. Where the quantity of shells is reasonably comparable to the fuel requirements, burning affords a convenient means of disposal. If, however, the quantity of shells is greatly in excess of fuel requirements, the practice of burning all the shells in boilers becomes expensive because of the greater maintenance necessary on boilers, flues, and stacks.

The heating values of some nut shells and fruit pits are shown in table 17.

Table 17.-*Heating value as fuel of some nut shells and fruit pits*

Material	B.t.u. per pound
Almond shells	8364 (48)
Apricot pits	8521 (48)
Chestnut shells	7895 (48)
Peach pits	8209 (48)
Peanut shells	8850 (35)
Pecan shells	8950 (35)

INDUSTRIAL PROCESSING

Dry Grinding

Industrial processing and dry grinding of nut shells and fruit pits includes operations associated with cleaning and storing incoming raw materials; transfer of the shells from storage; cracking and removal of kernels and other materials not desired in the ground products; grinding and classifying the products to both size and specific gravity; plant housekeeping; and merchandising.

In general, nut shells and fruit pits, being hard, friable materials, undergo size reduction by impact and attrition without much difficulty. The few shell materials which have fibrous characteristics may require cutting action to reduce their bulk during the initial stages of processing. Thorough consideration is given to these factors in a bulletin, "Dry Grinding of Agricultural Residues - A New Industrial Enterprise," AIC-336, published in May 1952 by the Northern Regional Research Laboratory, Peoria, Illinois *(20)*. In addition to giving data on actual grinding and on commercial as well as pilot-plant equipment, many difficulties and hazards of a grinding business are discussed. Dust explosions and fires in grinding plants are also given detailed consideration. Studies on the grinding of black-walnut shells to fine flours for the Tennessee Valley Authority are reported by Zarger *(63)*.

Preliminary reduction of nut shells and fruit pits is made with a high-speed hammer mill or with an attrition type of disc mill. The plate pattern selected for the preliminary reduction depends upon shell characteristics and the work to be accomplished at this stage. The reduction to fine particle size and flour takes place in attrition mills. Although mills of this type run hot in dry grinding, the possibility of the fine products catching fire is avoided by the proper use of water, steam, air, and inert gases in maintaining nonhazardous conditions in the grinding system. One method of using steam in a dry-grinding system is claimed in a patent granted to Ayers *(11)*. At the Northern Laboratory steam is introduced into the pneumatic collecting system at the discharge of the attrition mill. This has been very effective in preventing explosions and fires.

Cost of Grinding Plants

Construction costs of shell-grinding plants vary with location, accessibility and condition of the raw materials, the type and capacity of equipment, and upon the nature of the markets for the finished products. Costs of structures for processing and storage for areas of different average climatic conditions will, of course, vary. Equipment costs depend upon the type of grinding and classifying equipment selected, and the extent of cleaning that must be performed at the grinding plant.

Taking these factors into consideration, and based on new construction and equipment, a grinding plant having an hourly capacity of 1 to 1-1/2 tons or more may involve expenditures of $60,000 and upward. Investment capital should be sufficient to finance plant operations during the period when sales outlets are being built up.

ACKNOWLEDGMENTS

The authors wish to acknowledge the valuable assistance of staff members of this Laboratory and the cooperation of various nut shellers and food processors who have made this presentation possible. Mention of the cooperating organizations listed below does not constitute an endorsement or recommendation but is made as an expression of appreciation for the service rendered in the conduct of this project:

Agrashell, Inc.

Sewall S. Brown and Company

California Almond Growers Exchange

California Date Growers Association

California Walnut Growers Association

R. T. Collier Corporation

Durkee Famous Foods

R. E. Funsten Company

Gravette Shelling Company

Harwick Std. Chemical Company

Lufkin Pecan Shelling Company

Madeira Food and Material Company

Northwest Nut Growers, Inc.

H. H. Shufeldt and Company

Bernard Sirotta Company

Wenatchee Foods, Inc.

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